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PACIFIC NORTH WEST FOREST AND RANGE EXPERIMENT STATION

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EVALUATION OF THE BOEING-VERTOL 107 HELICOPTER AND SPRAY SYSTEM FOR FOREST APPLICATION OF INSECTICIDE

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ABSTRACT

The distribution of insecticide sprays produced from a Boeing-Vertol 107 helicopter and spray system was evaluated under open ground conditions. The Vertol produced a spray pattern similar to that of other helicopters and was found suitable for forest spraying. The swath width varied with the nozzle arrangement on the boom. The outboard nozzle arrangement resulted in the widest acceptable swath width, the lowest deposit across the swath, and the lowest spray recovery. The inboard nozzle arrangement resulted in a moderate swath width, the highest deposit across the swath, and the highest percent spray recovery.

Keywords: Helicopters, pesticide application methods, spraying (-pest control.

INTRODUCTION

An aerial spray program to control the Douglas-fir tussock moth with the insecticide DDT was planned for late spring and early summer of 1974. This involved several hundred thousand acres in parts of northeastern Oregon, southeastern Washington, and western Idaho. Because helicopters have the ability to fly slower and closer to the target, thus applying sprays in mountainous areas with more accuracy, they were chosen by the Forest Service over conventional fixed-wing crafts to apply the pesticide.

The Forest Service anticipated a helicopter shortage because (a) the total spray area was large, (b) each unit had to be sprayed within a specified time interval, and (c) most helicopters used for agricultural spraying have small pay loads. In light of this potential shortage, the Aerial Applications Project of the Pacific Northwest Forest and Range Experiment Station has evaluated the Boeing-Vertol 107 helicopter and spray system for forest application of insecticide. The Vertol 107 is a very large double-rotored helicopter commonly used for aerial logging in the Northwest.

DESCRIPTION OF SPRAY EQUIPMENT

The helicopter and spray system (fig. 1) were furnished and operated by Columbia Construction Helicopters, Inc.,

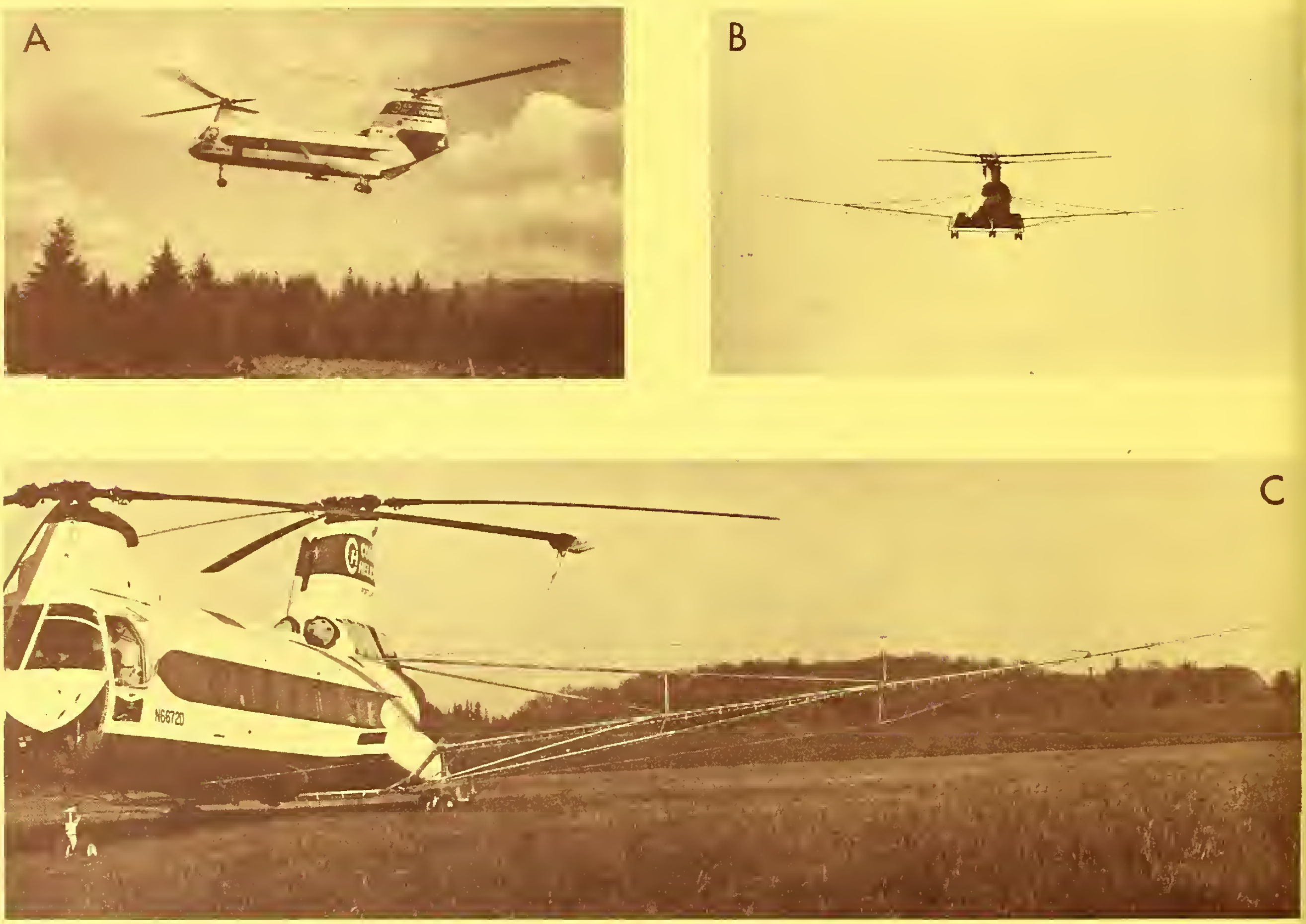

Figure 1.--Boeing-Vertol 107 helicopter and spray system: (A) helicopter, (B) helicopter and spray system in flight, (C) left spray boom on helicopter.

of Portland, Oregon.[1] The helicopter has double rotors and twin turbine engines. Each rotor blade is 25 feet (7.62 m) long, with 33 feet, 4 inches (10.16 m) between the forward and aft rotor shaft. Figure 2 shows the horizontal position of the forward and aft rotor relative to the position of the boom. The gross weight of the ship is 19,000 pounds (8618.4 kg) with a pay load of approximately 8,000 pounds (3628.8 kg). The spray system was a prototype designed by Columbia Construction Helicopters, Inc. The internally mounted system essentially consisted of a 250-gallon (946.35-liter) aluminum spray tank, two gasoline engines with direct drive pumps, a left and right spray boom, and a cross-over boom. The spray tank would presumably be replaced with an 800- to

[1] The use of trade, firm, or corporation names is for the information and convenience of the reader. Such use does not constitute endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

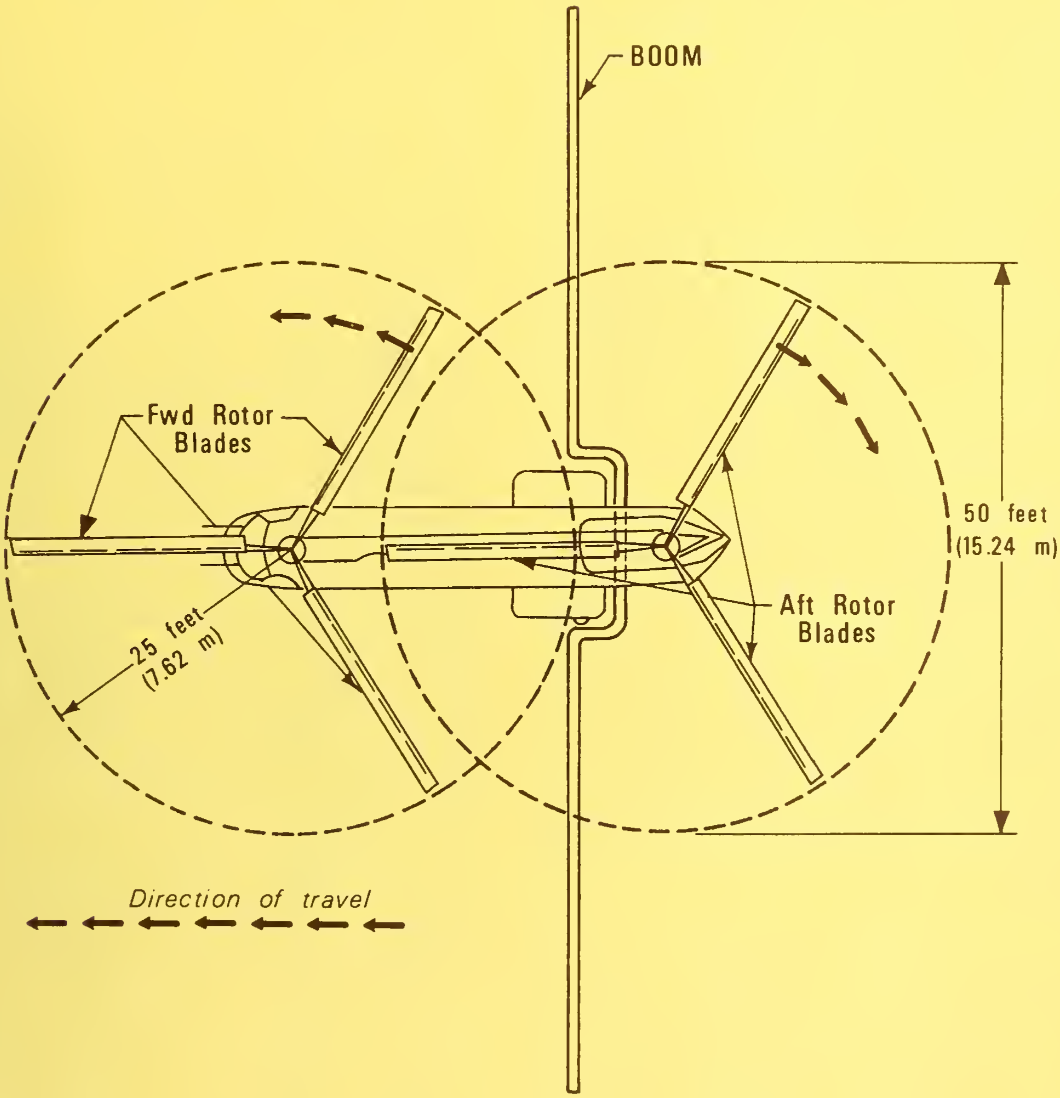

Figure 2.--Schematic showing the horizontal position of the forward and aft rotor relative to the boom.

1,000-gallon (3028.32- to 3785.4-liter) capacity tank for operational use. The two gasoline-driven engines with direct drive pumps were rated at 8.5 horsepower each, with a pump capacity of approximately 50 gallons (189.27 liters) per minute at 40 pounds per square inch (2.76×10^6 dyne/cm^2). A 12-volt battery was used for starting the engines. The spray booms were made of aluminum with rubber hoses connecting the crossover spray boom to the left and right spray boom. The crossover boom was 2-inch (5.08-cm) pipe approximately 15 feet (4.57 m) long. The left and right spray booms had two diameter reductions from inboard to outboard, which were from 2 inches (5.08 cm) to 1-1/2 inches (3.81 cm) to 1 inch (2.54 cm). Each boom was approximately 41 feet (12.50 m) long, making the total span of the booms 97 feet (29.57 m). The booms were supported by aluminum tubing and stainless steel cable leading from the airframe hard points to various points on the boom.

TEST PROCEDURE

The purpose of these tests was to obtain data concerning the swath width and deposit pattern produced by the Vertol 107 helicopter and spray system. The test procedure used was similar to that used by Orchard et al. (1974). The spraying speed, atomization, pressure, nozzle size, and spray height were constant; therefore the only variable tested was nozzle arrangements along the boom which were (1) evenly spaced, (2) inboard, or (3) outboard.

The spray formulation used was No. 2 fuel oil plus a fluorescent tracer. To each gallon (3.78 liters) of spray, 3.785 g (0.1 percent weight to volume) of the fluorescent tracer Rhodamine B Extra Base was added to facilitate deposit assessment.

Initially, the spray system was calibrated at a spray pressure of 40 pounds per square inch (2.76×10^6 dyne/cm^2) for an application rate of 1 gallon per acre (9.35 liters/ha) and assumed swath width of 300 feet (91.44 m). For flights 13-16, the spray system was calibrated for a 400-foot (121.92-m) swath to determine whether the swath width could be extended. To determine whether the spray was being delivered at equal rates throughout the boom, flow rates were established from nozzles at two inboard and two outboard positions on the boom. The formulation was sprayed through the nozzles and collected for 1 minute, then measured in a graduate cylinder, thus providing the flow rate per minute. All nozzles were oriented downward at 90° with respect to the line of flight. The nozzle arrangement on the boom for each treatment parameter is shown in figure 3.

The procedure used for determining the spray distribution was similar to that reported by Isler and Yuill (1964) for fixed-wing aircraft and by Isler and Maksymiuk (1961) for helicopters. A 500-foot (152.4-m) rotating platform was used for holding the deposit sampling surfaces. Sampling surfaces consisted of one 6- by 6-inch (15.24- by 15.24-cm) aluminum plate and one white 4- by 5-inch (10.16- by 12.7-cm) Kromekote card placed at 10-foot (3.05-m) intervals along the entire length of the platform. The platform was rotated for each test flight until it was perpendicular to the prevailing wind. The aircraft was flown upwind over the platform at a predetermined spot and at a designated speed and altitude. The spray was turned on 500 feet (152.4 m) downwind of the platform and turned off 1,500 feet (457.2 m) upwind of the platform. After turning off the spray, the pilot continued in a straight line for 5 seconds, then made a large turn and landed downwind of the platform so that the air currents in the direct vicinity of the sampling stations would not be disturbed.

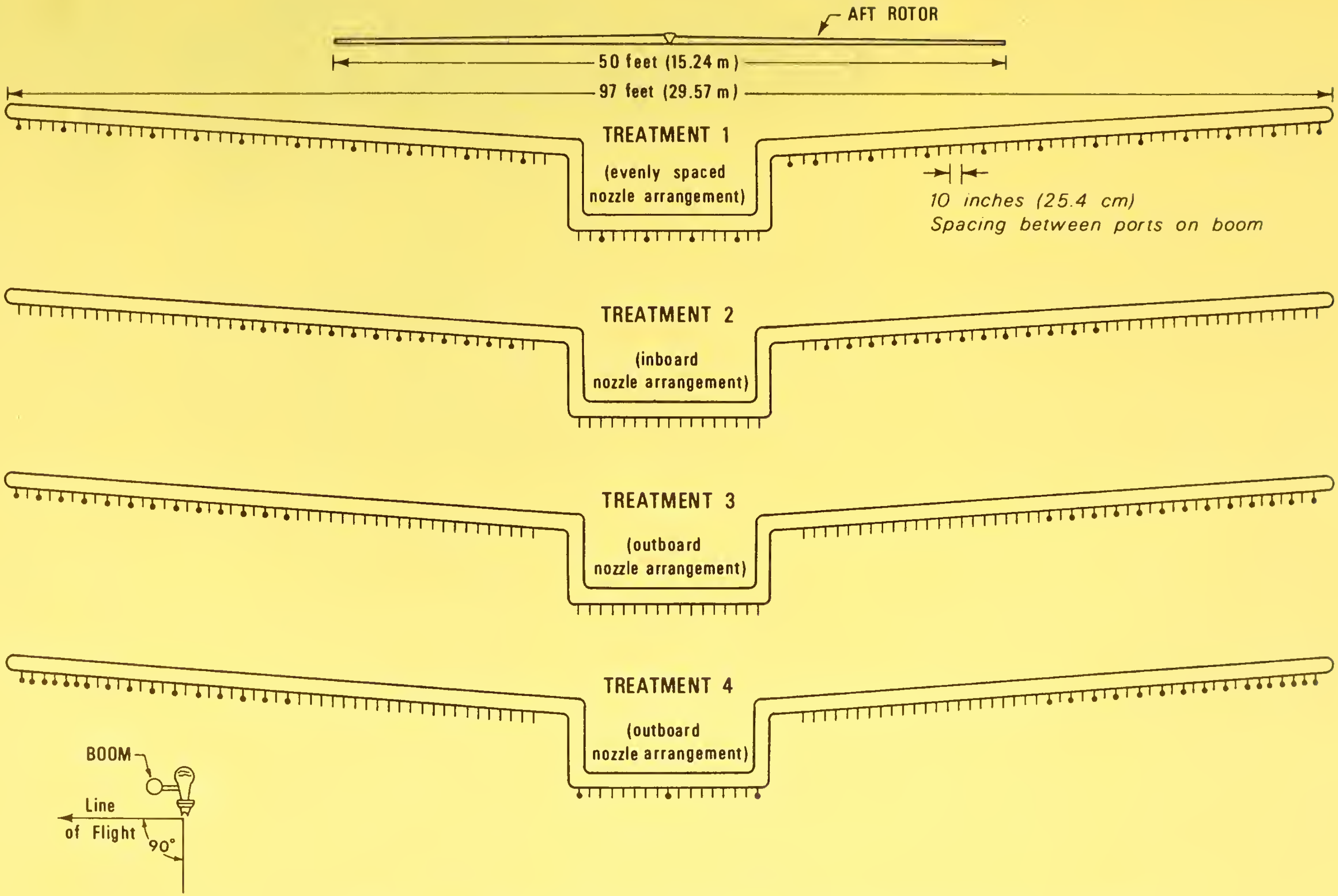

Figure 3.--Schematic showing the nozzle arrangement on the boom for each treatment.

The meteorological conditions were monitored for each test flight, as shown in table 1. Most flights were made in the early morning, when spraying conditions are usually favorable. Of 16 flights conducted, 5 were discarded because the wind changed direction during the flight causing a large part of the spray to miss the platform.

The spray was allowed to settle for 15-20 minutes; then the deposit sampling surfaces were collected and placed in slotted boxes to prevent smudging of drops and contamination of one surface by another. The boxes were then transported to the laboratory for analysis.

The spray drops on the white Kromekote cards were counted and size measured with a Quantimet 720 image analyser and ultraviolet illuminator. The spray atomization was determined by the drop-size spectra method (Maksymiuk 1964). The number of drops are expressed in number per square centimeter of surface area, and the size (atomization) is expressed as the volume median diameter (vmd).[2/]

The spray deposit was washed from each of the aluminum plates with 10 ml of 95-percent ethanol. The deposit recovered from the plates was quantitated fluoremetrically, using a Model 430 Turner Spectrofluorometer, similar to the method described by Yates and Akesson (1963). The quantity of spray is expressed in gallons per acre (gpa) and liters per hectare.

RESULTS AND DISCUSSION

Calibration

Flow rates at the different locations along the boom are shown in table 2. The flow rate for nozzles located on the left inboard, left outboard, and right outboard part of the boom were very nearly equal with very little variation. The right inboard nozzle had a flow rate 5.9 percent greater than at the other locations and was consistently greater for each of the four replications. Since the difference was small, we did not determine whether this difference was a result of the spray system design or the nozzle. The gasoline-engine-driven spray pump, which is independent of the helicopter engine, allowed for easy calibration on the ground.

Swath Width

Table 3 shows the swath width, swath deposit, percent recovery, and atomization for each test flight. For our purpose, an acceptable swath width was defined as that portion of the swath having a deposit level of 0.1 gpa (0.935 liter per ha) or greater at each sampling point throughout the swath. A comparison of the nozzle arrangement on the boom shows that the outboard arrangement (treatment 3) resulted in a wider acceptable swath width. The swath width obtained with the outboard nozzle arrangement calibrated for a 400-foot (121.92-m) swath (treatment 4) was somewhat smaller but resulted in a higher average swath deposit. The inboard nozzle arrangement (treatment 2) resulted in a wider swath width than the evenly spaced nozzle arrangement (treatment 1). By placing the nozzle outboard, more spray is drawn into the vortices and released over a wider area as the vortices spread out and dissipate. Some of the flights were slight crosswind flights. The average swath width for the 11 flights was 254 feet (77.42 m).

The degree of atomization is a critical factor in determining swath widths. As the spray is further atomized, that is, drops become smaller, it is carried farther by the vortices and is affected more by prevailing meteorological conditions, hence more drift. Consequently,

[2/] Volume median diameter (vmd) is the drop diameter satisfying the requirement that half of the volume of liquid is in drops smaller and half in drops larger than the vmd.

Table 1--Summary of meteorological data

Flight number	Date (1974)	Time (a.m.)	Wind condition and speed, m/h (m/sec)				Wind direction (degrees)		Air temperature, °F (°C)						Relative humidity (percent)			Sky condition
			Gusty	at 4 feet (1.22 m)	at 16 feet (4.88 m)	at 40 feet (12.19 m)	at 4 feet (1.22 m)	at 40 feet (12.19 m)	at 4 feet (1.22 m)	at 8 feet (2.44 m)	at 16 feet (4.88 m)	at 24 feet (7.32 m)	at 32 feet (9.75 m)	at 40 feet (12.19 m)	at 4 feet (1.22 m)	at 16 feet (4.88 m)	at 40 feet (12.19 m)	
1	4-16	7:10	no	1 (0.45)	2 (0.89)	3 (1.34)	230	260	34 (1.1)	36 (2.2)	36 (2.2)	36 (2.2)	36 (2.2)	35 (1.7)	100	100	100	clear
2	4-16	7:30	no	1 (.45)	1-2 (.45-.89)	1 (.45)	270	260	36 (2.2)	38 (3.3)	36 (2.2)	38 (3.3)	37 (2.8)	36 (2.2)	100	100	--	clear
3	4-16	8:12	no	3 (1.34)	2 (.89)	2 (.89)	270	280	41 (5.0)	40 (4.4)	40 (4.4)	41 (5.0)	40 (4.4)	40 (4.4)	100	100	100	clear
4	4-16	8:50	no	1-2 (.45-.89)	1 (.45)	1 (.45)	285	300	42 (5.6)	43 (6.1)	42 (5.6)	46 (7.8)	43 (6.1)	42 (5.6)	100	98	100	clear
7	4-17	8:00	no	0-1 (0-.45)	0-1 (0-.45)	0-1 (0-.45)	180	170	40 (4.4)	40 (4.4)	41 (5.0)	40 (4.4)	41 (5.0)	42 (5.6)	100	100	100	clear
8	4-17	8:50	no	1-2 (.45-.89)	1-2 (.45-.89)	2 (.89)	120	100	48 (8.9)	48 (8.9)	47 (8.3)	49 (9.4)	47 (8.3)	47 (8.3)	90	100	100	clear
9	4-17	9:05	no	1 (.45)	2 (.89)	3-4 (1.34-1.79)	175	100	47 (8.3)	48 (8.9)	48 (8.9)	50 (10.0)	50 (10.0)	49 (9.4)	90	100	95	clear
10	4-17	10:05	slight	0 (0)	1 (.45)	1-2 (.45-.89)	--	20	54 (12.2)	53 (11.7)	52 (11.1)	54 (12.2)	54 (12.2)	54 (12.2)	80	90	82	clear
12	4-18	7:00	yes	2 (.89)	5 (2.24)	>8 (73.58)	310	290	44 (6.7)	45 (7.2)	46 (7.8)	46 (7.8)	47 (8.3)	47 (8.3)	100	100	100	overcast
13	4-18	8:20	no	1-2 (.45-.89)	1-2 (.45-.89)	1-2 (.45-.89)	310	300	48 (8.9)	47 (8.3)	49 (9.4)	48 (8.9)	48 (8.9)	48 (8.9)	100	100	100	overcast
15	4-19	8:45	yes	3-5 (1.34-2.24)	4-5 (1.79-2.24)	6 (2.68)	180	130	44 (6.7)	45 (7.2)	45 (7.2)	43 (6.1)	44 (6.7)	44 (6.7)	100	100	100	overcast

Table 2--Flow rate data for nozzles positioned at various points along the boom

Location of nozzle	Flow rate for SS 8020 nozzle tip at 40 pounds per square inch (2.76×10^6 dyne/cm^2)				
	Run 1	Run 2	Run 3	Run 4	Mean
	- - - - - *Gallons per minute (liters/min)* - - - - -				
Left inboard	2.04 (7.72)	2.07 (7.84)	2.06 (7.80)	2.04 (7.72)	2.05 (7.76)
Left outboard	2.04 (7.72)	2.05 (7.76)	2.03 (7.68)	2.00 (7.57)	2.03 (7.68)
Right inboard	2.12 (8.02)	2.18 (8.25)	2.17 (8.21)	2.12 (8.02)	2.15 (8.14)
Right outboard	-- (--)	2.04 (7.72)	2.02 (7.65)	1.99 (7.53)	2.02 (7.65)
Mean	2.07 (7.84)	2.08 (7.87)	2.07 (7.84)	2.03 (7.68)	2.06 (7.80)

Table 3--Swath width, swath deposit, percent recovery, and atomization for individual test flights using SS 8020 nozzle tips at a constant pressure of 40 pounds per square inch (2.76 × 10⁶ dyne/cm²), spray height of 70 feet (21.34 m), and spray speed of 90 miles per hour (40.23 m/sec)

Treatment and flight number	Swath width, feet (m)		Average swath deposit		Percent recovery	Atomization, µm (vmd)
	Calibrated	Actual[1]	Gallon per acre (liters/ha)	Drops per square centimeter		
1--evenly spaced nozzle arrangement:						
1	300(91.44)	310(94.49)	0.442(4.13)	49	47	150
2	300(91.44)	160(48.77)	.676(6.32)	70	40	158
3	300(91.44)	220(67.06)	.353(3.30)	53	31	151
4	300(91.44)	180(54.86)	.459(4.29)	71	33	150
Mean	--	218(66.45)	.482(4.51)	61	38	152
2--inboard nozzle arrangement:						
7	300(91.44)	250(76.20)	.569(5.32)	80	51	113
8	300(91.44)	260(79.25)	.420(3.93)	68	40	121
9	300(91.44)	220(67.06)	.498(4.66)	47	40	130
Mean	--	243(74.07)	.495(4.63)	65	44	121
3--outboard nozzle arrangement:						
10	300(91.44)	310(94.49)	.201(1.88)	34	24	136
12	300(91.44)	320(97.54)	.382(3.57)	29	42	152
Mean	--	315(96.01)	.292(2.73)	32	33	137
4--outboard nozzle arrangement:						
13	400(121.92)	330(100.58)	.441(4.12)	77	38	144
15	400(121.92)	230(70.10)	.462(4.32)	50	30	150
Mean	--	280(85.34)	.451(4.22)	64	34	147

[1] The swath width is that part of the swath having 0.1 gallon per acre (0.935 liters/ha) or greater at each sampling point.

the overall physical swath width will be wider, but the deposit level within the swath may not be acceptable.

Spray Deposit and Pattern

As shown in table 3, the highest swath deposit, both in terms of gallons per acre (liters per ha) and number of drops per square centimeter, was achieved by the inboard nozzle arrangement treatment. The outboard nozzle arrangement (treatment 3) resulted in the widest swath width, the smallest deposit across the swath in terms of gallons per acre (liters/ha) and number of drops per square centimeter, and the smallest percent recovery.

Figures 4-7 show the spray pattern of individual flights for each test. There are no two patterns alike, but there are similarities. The swath width produced by this helicopter is wider, but the deposit pattern similar, to the smaller single rotor helicopters and suitable for forest spraying. The effects of the double rotor on spray distribution are unknown, but it is thought to reduce the strength or velocity of the vortex. By using a dyed spray, the vortices produced by the rotor blades become visible and can be observed as the spray is entrapped by these vortices. Visual observation shows the Boeing 107 having a weaker vortex than the Bell 205. Since the distance between the boom and rotor blades is much greater on the Boeing 107 than on the Bell 205, there may not have been enough spray entrapped in the vortex to portray its full size and intensity.

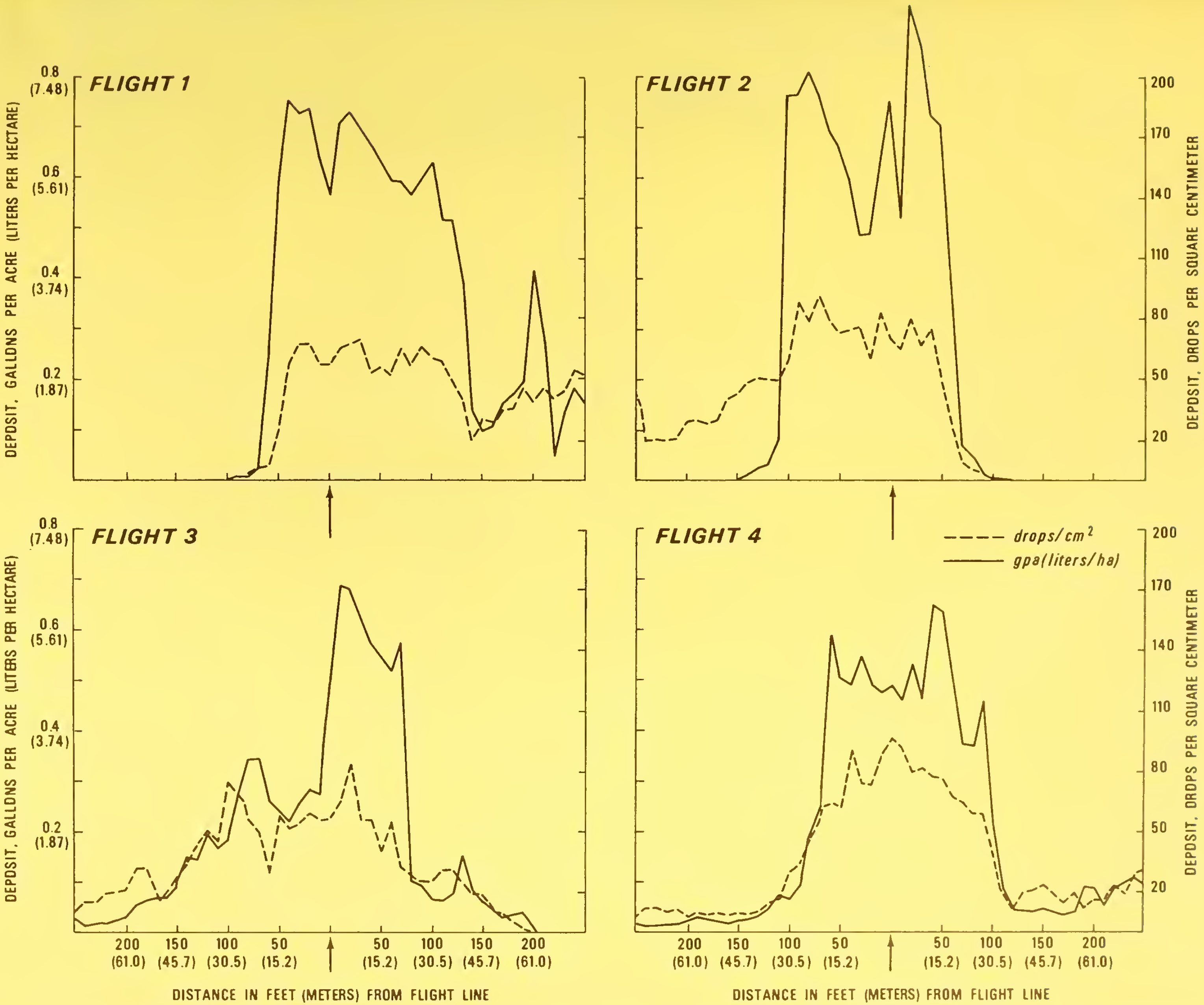

Figure 4.--Spray pattern for individual flights. Treatment 1: Evenly spaced nozzle arrangement, calibrated for a 300-foot (91.44 m) swath.

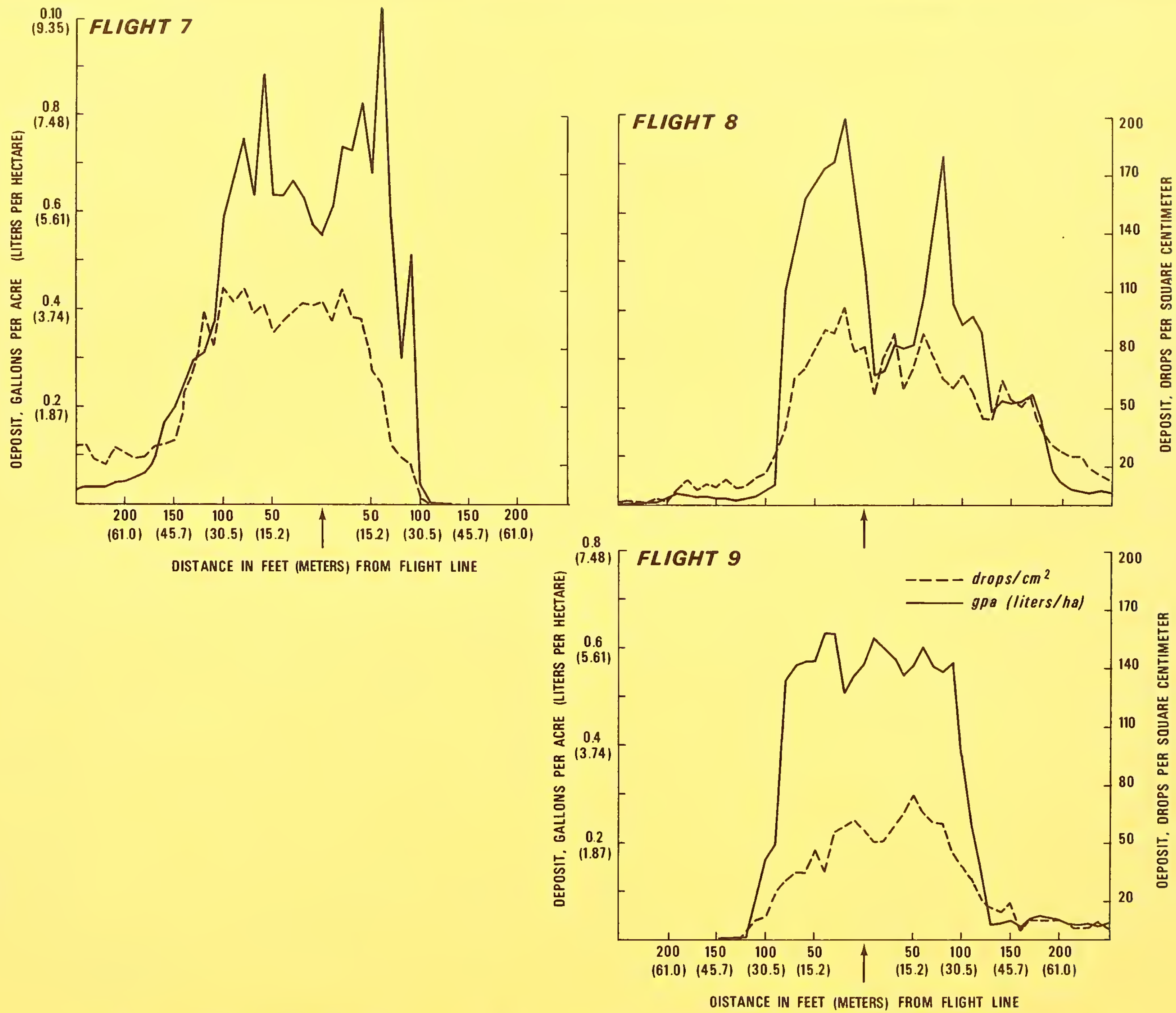

Figure 5.--Spray pattern for individual flights. Treatment 2: Inboard nozzle arrangement, calibrated for a 300-foot (91.44 m) swath.

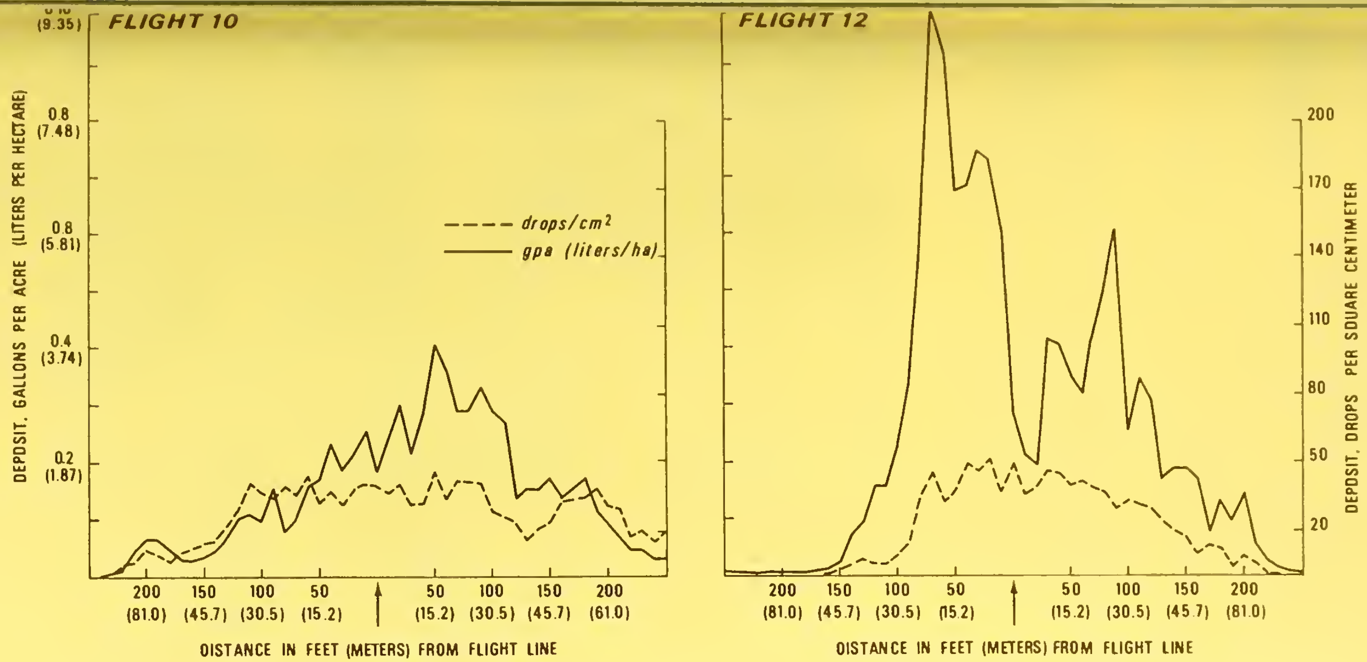

Figure 6.--Spray pattern for individual flights. Treatment 3: Outboard nozzle arrangement, calibrated for a 300-foot (91.44 m) swath.

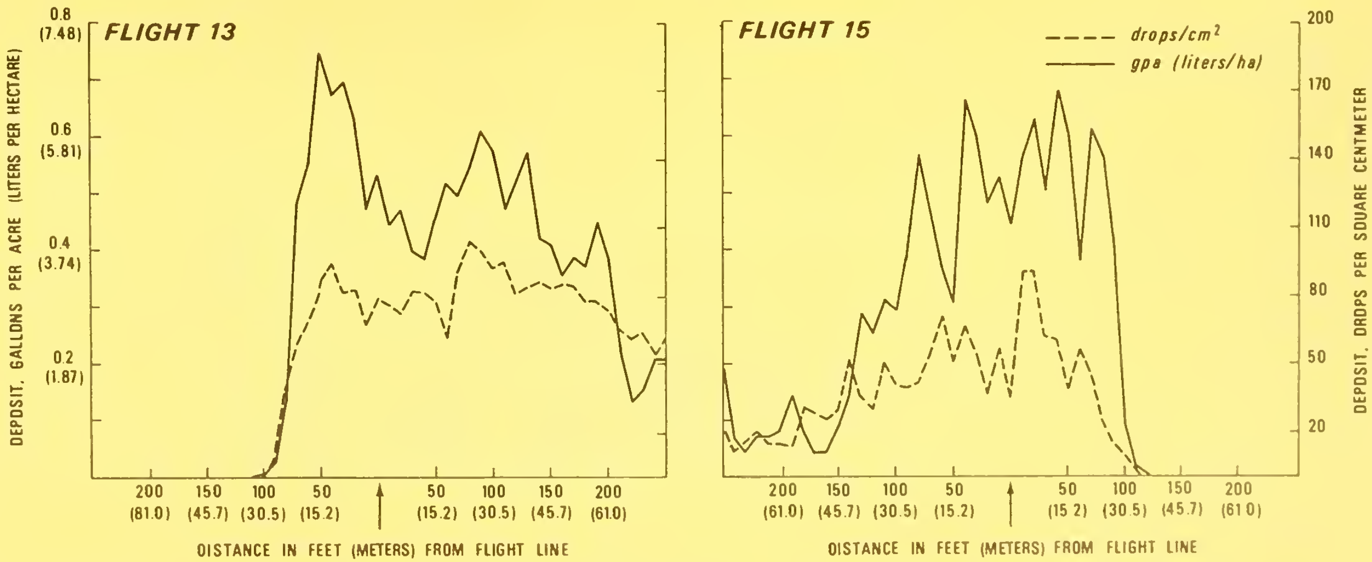

Figure 7.--Spray pattern for individual flights. Treatment 4: Outboard nozzle arrangement, calibrated for a 400-foot (121.92 m) swath.

SPRAY RECOVERY AND ATOMIZATION

On the average, 38 percent of the spray was recovered on the sampling platform, with a range of 24-51 percent. The spray recovery rate is about the same as that from other helicopters operating under similar conditions. The average atomization for all test flights was 141-µm vmd. The volume median diameter is slightly, but consistently, smaller for the inboard nozzle arrangement flights. Figure 2 shows that the forward rotor blade tips are directly over the inboard part of the boom. The vortices formed by both rotor tips may be causing an increased shear over a sufficient number of nozzles to result in a lower volume median diameter.

CONCLUSIONS

1. The right inboard nozzle consistently had a higher flow rate than nozzles at other locations.

2. The spray system was very easy to calibrate, and the boom could be rotated to adjust nozzle orientation with respect to the line of flight.

3. The outboard nozzle arrangement produced the widest swath width, the smallest deposit across the swath, and the smallest percent recovery.

4. The inboard nozzle arrangement gave a moderate swath width, with the largest deposit across the swath and the highest spray recovery.

5. The inboard nozzle arrangement resulted in a smaller volume median diameter.

6. In general, it was concluded that the Boeing-Vertol 107 helicopter and prototype spray system was a satisfactory tool for aerial application of pesticides. The swath deposit, pattern, and spray recovery were found to be typical of that of other spray systems operated under similar conditions. General operation of the helicopter, maneuverability, and ease of working with the spray system in changing nozzles and calibration were all found to be satisfactory. It is expected that the prototype spray system would be altered for operational use, such as replacing the existing spraytank with a larger one and installing an emergency spray dump.

7. This aircraft should be further tested to establish the effect of rotor wake, vortices, and downwash on dispersal of the spray under open ground and forest conditions.

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